(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 September 2001 (07.09.2001)

PCT

(10) International Publication Number
WO 01/64213 A1

(51) International Patent Classification[7]: A61K 31/44, C07D 401/00

(21) International Application Number: PCT/US01/06837

(22) International Filing Date: 2 March 2001 (02.03.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/186,418 2 March 2000 (02.03.2000) US

(71) Applicant *(for all designated States except US)*: SMITHKLINE BEECHAM CORPORATION [US/US]; One Franklin Plaza, Philadelphia, PA 19103 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: BONDINELL, William, E. [US/US]; 1512 Franklin Lane, Wayne, PA 19087 (US). KU, Thomas, W. [US/US]; 1413 Southwind Way, Dresher, PA 19025 (US).

(74) Agents: STEIN-FERNANDEZ, Nora et al.; SmithKline Beecham Corporation, Corporate Intellectual Property, UW2220, 709 Swedeland Road, P.O. Box 1539, King of Prussia, PA 19406-0939 (US).

(81) Designated States *(national)*: AE, AL, AU, BA, BB, BG, BR, BZ, CA, CN, CO, CZ, DZ, EE, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KP, KR, LC, LK, LR, LT, LV, MA, MG, MK, MN, MX, MZ, NO, NZ, PL, RO, SG, SI, SK, SL, TR, TT, TZ, UA, US, UZ, VN, YU, ZA.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/64213 A1

(54) Title: COMPOUNDS AND METHODS

(57) Abstract: This invention relates to substituted benzanilides which are modulators, agonists or antagonists, of the CCR5 receptor. In addition, this invention relates to the treatment and prevention of disease states mediated by CCR5, including, but not limited to, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, atherosclerosis, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, and inflammatory bowel disease, all in mammals, by the use of substituted benzanilides which are CCR5 receptor antagonists. Furthermore, since CD8+ T cells have been implicated in COPD, CCR5 may play a role in their recruitment and therefore antagonists to CCR5 could provide potential therapeutic use in the treatment of COPD. Also, since CCR5 is a co-receptor for the entry of HIV into cells, selective receptor modulators may be useful in the treatment of HIV infection.

COMPOUNDS AND METHODS

FIELD OF THE INVENTION

This invention relates to spiropiperidine-containing benzanilides which are modulators, agonists or antagonists, of the CC chemokine receptor CC-CKR5 now designated as CCR5 (*Nature Medicine* **1996**, *2*, 1174-8), methods for their preparation, pharmaceutical compositions containing them and their use in treating disease. In addition, this invention relates to the treatment and prevention of disease states mediated by CCR5.

BACKGROUND OF THE INVENTION

T cells are not only key regulators of the immune response to infectious agents but are believed critical for the initiation and maintenance of the inflammatory reaction in a variety of chronic diseases. Increased numbers or enhanced activation state of T cells, especially CD4+ T cells, have been demonstrated in the synovium of individuals with rheumatoid arthritis (M.J. Elliott and R. N. Maini, Int. Arch. Allergy Immunol. 104: 112-1125, 1994), in the bronchial mucosa of asthmatics (C.J. Corrigan and A.B. Kay, Immunol. Today 13: 501-506, 1992), in the lesions of multiple sclerosis (R. Martin and H. F. McFarland, Crit. Rev. Clin. Lab. Sci. 32: 121-182, 1995), in psoriatic lesions (J.L. Jones, J. Berth-Jone, A. Fletcher and P.E. Hutchinson, J. Pathol. 174: 77-82, 1994) and in the fatty streaks of atherosclerosis (R. Ross, Annu. Rev. Physiol. 57: 791-804, 1995).

T cells, as well as other inflammatory cells, will migrate into tissues in response to the production of a variety of chemotactic factors. Among these factors are a superfamily of 8-12 kDa proteins known as the chemokines. These proteins share structural features such as the presence of 3-4 conserved cysteine residues. RANTES, which stands for Regulated upon Activation Normal T cell Expressed and Secreted, is a 8 kDa protein member of CC branch of the chemokine family. These proteins recruit and activate immune and inflammatory cells through an interaction with G-protein coupled receptors. The CC branch is defined by the absence of an intervening amino acid residue between the first two cysteine residues and members of this family predominately elicit the migration of mononuclear cells, eosinophils and basophils (M. Baggiolini, B. Dewald, and B. Moser, Adv. Immunol. 55: 97-179, 1994; and J.J. Oppenheim, C.O.C. Zachariae, N. Mukaida, and K. Matsushima, Annu. Rev. Immunol. 9: 617-648, 1991).

RANTES potently produces chemotaxis of T cells, basophils, eosinophils, monocytes and mast cells. RANTES was originally identified as gene product induced late after antigen activation of T-cells (T.J. Schall, J. Jongstra, B.J. Dyer, J. Jorgensen, et al., J. Immunol. 141:1018-1025, 1988), however, RANTES has been shown to be synthesized and secreted by a diverse group of cells that include epithelial and endothelial cells (C. Stellato, L.A. Beck, G.A. Gorgone, D. Proud, et al., J. Immunol. 155: 410-418, 1995; and A. Marfaing-Koka, O. Devergne, G. Gorgone, A. Portier, et al., J. Immunol. 154: 1870-1878, 1994), synovial fibroblasts (P. Rathanaswami, M. Hachicha, M. Sadick, T.J. Schall, et al., J. Biol. Chem. 268: 5834-5839, 1993) and dermal fibroblasts (M. Sticherling, M. Kupper, F. Koltrowitz, E. Bornscheuer, et al., J. Invest. Dermatol. 105: 585-591, (1995), mesangial cells (G. Wolf, S. Aberle, F. Thaiss, et al., Kidney Int. 44: 795-804, 1994) and platelets (Y. Koameyoshi, A. Dorschner, A.I. Mallet, E. Christophers, et al., J. Exp. Med. 176: 587-592, 1992). In these cells, RANTES mRNA is rapidly upregulated in response to IL-1 or TNFα. Although RANTES mRNA is not usually detected in normal tissues (J.M. Pattison, P.J. Nelson, and A.M. Krensky, Clin. Immunother. 4: 1-8, 1995), increased mRNA or protein has been found in diseases characterized by a mononuclear infiltrate. For example, RANTES mRNA was visualized using *in situ* hybridization in renal allografts undergoing rejection (J.M. Pattison, P.J. Nelson, and A.M. Krensky, Clin. Immunother. 4: 1-8, 1995; and K.C. Nadeau, H. Azuma and N.I. Tilney, Proc. Natl. Acad. USA 92: 8729-8733, 1995) in the skin of atopic dermatitis patients after exposure to antigen (S. Ying, L. Taborda-Barata, Q. Meng, M. Humbert, et al., J. Exp. Med. 181: 2153-2159, 1995), and in endothelial cells of coronary arteries undergoing accelerated atherosclerosis after cardiac transplant (J.M. Pattison, P.J. Nelson, and A.M. Krensky, Clin. Immunother. 4: 1-8, 1995). Further, increased immunoreactive protein for RANTES has been detected in bronchoalveolar lavage fluid (R. Alam, J. York, M. Boyers, et al., Am. J. Resp. Crit. Care Med. 149: A951, 1994) and sputum from asthmatic individuals (C.M. Gelder, P.S. Thomas, D.H. Yates, I.M. Adcock, et al., Thorax 50: 1033-1037, 1995).

Several receptors have been identified that bind RANTES. In particular, CCR5, when expressed in either HEK 293 cells or CHO cells, binds RANTES. This receptor is expressed in T-cells and in monocytes and macrophages, immune/inflammatory cells which are important in the maintenance of a chronic inflammatory reaction. Pharmacological characterization of CCR5 indicates similarities to the RANTES binding site observed on isolated T cells. Therefore, antagonism of RANTES' action on CCR5, as well as antagonism of other natural

modulators of CCR5, should inhibit the recruitment and activation of T cells and macrophages into inflammatory lesions and provide a novel therapeutic approach for the treatment of atopic and autoimmune disorders.

Since T cells express CCR5, selective receptor modulators of CCR5, particularly antagonists, are likely to provide beneficial effects in diseases including, but not limited to, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, atherosclerosis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, and inflammatory bowel disease, all in mammals, preferably humans. Furthermore, since CD8+ T cells have been implicated in chronic obstructive pulmonary disease (COPD), CCR5 may play a role in their recruitment and therefore antagonists to CCR5 could provide potential therapeutic use in the treatment of COPD. Also, since CCR5 is a co-receptor for the entry of HIV into cells, selective receptor modulators may be useful in the treatment of HIV infection.

Spiropiperidine-containing benzanilides have been reported to have 5-HT receptor activity; in international application publication number WO 97/10824 published 27 March 1997; international application publication number WO 96/11934 published 25 April 1996; international application publication number WO 96/19477 published 27 June 1996; international application publication number WO 97/17350 published 15 May 1997; international application publication number WO 97/34900 published 25 September 1997; international application publication number WO 97/34901 published 25 September 1997; international application publication number WO 97/35861 published 2 October 1997; and international application publication number WO 97/35862 published 2 October 1997. In addition, WO 99/01127, published January 14, 1999, and co-pending application Attorney Docket Number P50883, filed December 30, 1998, disclose substituted benzanilides useful for modulating CCR5-mediated diseases.

Surprisingly, it has now been discovered that this class of non-peptide compounds, in particular spiropiperidine-containing benzanilides of formula (I), function as CCR5 receptor modulators, and therefore, have utility in the treatment and prevention of disease states mediated by CCR5 receptor mechanisms. Further, it has been discovered that the spiropiperidine-containing benzanilides compounds of formula (I) are dual antagonists, i.e., they antagonize both human and murine CCR5. Therefore, this invention also relates to a method for modulating human and murine

CCR5 with spiro-substituted compounds in general, and the compounds of formula (I) in particular.

SUMMARY OF THE INVENTION

The present invention is to compounds of formula (I) and their use as CCR5 modulators for the treatment of certain disease states, including, but not limited to, COPD, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, atherosclerosis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, inflammatory bowel disease, and HIV infection, all in mammals, preferably humans. The preferred compounds for use as CCR5 modulators herein are those compounds of formula (I) as noted.

The present invention further provides pharmaceutical compositions containing a therapeutically effective amount of a compound of formula (I), including pharmaceutically acceptable salts and hydrates thereof, in combination with a pharmaceutically acceptable carrier, which compositions are suitable for the treatment of the CCR5-mediated diseases.

DETAILED DESCRIPTION OF THE INVENTION

It has now been discovered that spiropiperidine-containing benzanilides of formula (I) are potent CCR5 receptor modulators. Selective inhibition of CCR5 receptor mechanisms by treatment with the receptor modulators of formula (I), or a pharmaceutically acceptable salt thereof, represents an effective therapeutic and preventative approach to the treatment of a variety of disease states, including, but not limited to, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, atherosclerosis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, and inflammatory bowel disease, all in mammals, preferably humans. Furthermore, since CD8+ T cells have been implicated in COPD, CCR5 may play a role in their recruitment and therefore antagonists to CCR5 could provide potential therapeutic use in the treatment of COPD. Also, since CCR5 is a co-receptor for entry into cells, selective receptor modulators may be useful in the treatment of HIV infection.

In addition, it has been discovered that the spiropiperidine-containing benzanilides of formula (I) are particularly useful in that they modulate both the human and murine CCR5 receptors.

Preferred compounds for use as CCR5 modulators are those compounds of formula (I) as noted herein.

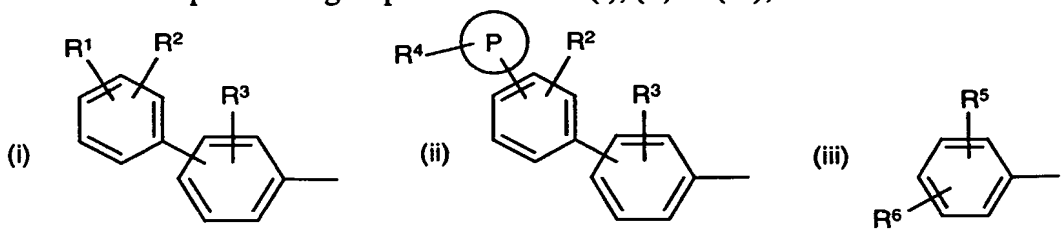
Each of these references is incorporated herein in their entirety.

A preferred group of compounds for use herein are those compounds of the formula (I) or a pharmaceutically acceptable salt thereof:

Ar—A—E

Formula I

in which Ar represents a group selected from (i), (ii) or (iii);



wherein:

the basic nitrogen in moiety E may optionally be quaternized with C_{1-6}alkyl or is optionally present as the N-oxide;

R^1 and R^2 are independently one or more of hydrogen, C_{1-6}alkyl, C_{2-6}alkenyl, C_{2-6}alkynyl, C_{3-7}cycloalkyl, C_{3-6}cycloalkenyl, aryl, $(CH_2)_aNR^7R^8$, $(CH_2)_aNR^7COR^9$, $(CH_2)_aNR^7CO_2R^{10}$, $(CH_2)_aNR^7SO_2R^{11}$, $(CH_2)_aCONR^{12}R^{13}$, hydroxyC_{1-6}alkyl, C_{1-4}alkoxyalkyl (optionally substituted by a C_{1-4}alkoxy or hydroxy group), $(CH_2)_aCO_2C_{1-6}$alkyl, $(CH_2)_bOC(O)R^{14}$, CR^{15}=NOR^{16}, CNR^{15}=NOR^{16}, COR^{17}, $CONR^{12}R^{13}$, $CONR^{12}(CH_2)_cOC_{1-4}$alkyl, $CONR^{12}(CH_2)_aCO_2R^{18}$, $CONHNR^{19}R^{20}$, $CONR^{12}SO_2R^{21}$, CO_2R^{22}, cyano, trifluoromethyl, NR^7R^8, NR^7COR^9, $NR^{23}CO(CH_2)_aNR^{23}R^{24}$, $NR^{23}CONR^{23}R^{24}$, $NR^7CO_2R^{10}$, $NR^7SO_2R^{11}$, N=$CNR^{23}NR^{23}R^{24}$, nitro, hydroxy, C_{1-6}alkoxy, hydroxyC_{1-6}alkoxy, C_{1-6}alkoxyC_{1-6}alkoxy, $OC(O)NR^{25}R^{26}$, SR^{27}, SOR^{28}, SO_2R^{28}, $SO_2NR^{25}R^{26}$ or halogen;

R^3 and R^4 are independently one or more of hydrogen, C_{1-6}alkyl, C_{3-7}cycloalkyl, C_{3-6}cycloalkenyl, hydroxyC_{1-6}alkyl, C_{1-6}alkylOC_{1-6}alkyl, $CONR^{29}R^{30}$, CO_2R^{31}, cyano, aryl, trifluoromethyl, $NR^{29}R^{30}$, nitro, hydroxy, C_{1-6}alkoxy, acyloxy or halogen;

R^5 is one or more of hydrogen, C_{1-6}alkyl, C_{1-6}alkoxy or halogen;

R^6 is one or more of hydrogen, C_{1-6}alkyl, C_{3-7}cycloalkyl (optionally substituted by a hydroxy or an oxo group), hydroxyC_{1-6}alkyl, hydroxyC_{3-6}alkenyl, hydroxyC_{3-6}alkynyl, $(CH_2)_dOR^{32}$, $(CH_2)_dCOR^{33}$, $(CH_2)_dCR^{34}{=}NOR^{35}$, $CONR^{36}R^{37}$, CO_2R^{38}, hydroxy, $O(CH_2)_eR^{39}$, $NR^{36}R^{37}$, SR^{40}, $SO_2NR^{41}R^{42}$ or halogen; or, R^5 and R^6 form a fused benzo ring optionally substituted with C_{1-6} alkyl, C_{1-6}alkoxy or halogen;

R^7 and R^8 are independently hydrogen or C_{1-6}alkyl, or together with the nitrogen to which they are attached, R^7 and R^8 form a 5- to 6-membered heterocyclic ring, which ring may optionally be substituted by an oxo group and, which, when the ring is 6-membered, may optionally contain in the ring one oxygen or sulfur atom;

R^9 is hydrogen, C_{1-6}alkyl or C_{1-4}alkoxyalkyl;

R^{10} is C_{1-6}alkyl;

R^{11} is C_{1-6}alkyl or phenyl;

R^{12} and R^{13} are independently hydrogen or C_{1-6}alkyl, or together with the nitrogen to which they are attached, R^{12} and R^{13} form a 5- to 6-membered heterocyclic ring, which, when the ring is 6-membered, may optionally contain in the ring one oxygen or sulfur atom;

R^{14} is C_{1-4}alkyl, optionally substituted by C_{1-6}alkoxy;

R^{15} and R^{16} are independently hydrogen or C_{1-6}alkyl;

R^{17} is hydrogen or C_{1-6}alkyl;

R^{18} is hydrogen or C_{1-6}alkyl;

R^{19} and R^{20} are independently hydrogen or C_{1-6}alkyl;

R^{21} is hydrogen or C_{1-6}alkyl;

R^{22} is hydrogen or C_{1-6}alkyl optionally substituted with one or two substituents selected from C_{1-6}alkyl, C_{1-6}alkoxy, hydroxy, or NR^7R^8;

R^{23} and R^{24} are independently hydrogen or C_{1-6}alkyl;

R^{25} and R^{26} are independently hydrogen or C_{1-6}alkyl, or together with the nitrogen to which they are attached, R^{25} and R^{26} form a 5- to 6-membered heterocyclic ring, which, when the ring is 6-membered, may optionally contain in the ring one oxygen or sulfur atom;

R^{27} is hydrogen or C_{1-6}alkyl;

R^{28} is C_{1-6}alkyl;

R^{29}, R^{30} and R^{31} are independently hydrogen or C_{1-6}alkyl;

R^{32} is C_{1-6}alkyl, hydroxyC_{1-6}alkyl, or C_{1-4}alkanoyl;

R^{33} is hydrogen or C_{1-6}alkyl;

R^{34} is hydrogen or C_{1-6}alkyl;

R^{35} is hydrogen or C_{1-6}alkyl;

R^{36} and R^{37} are independently hydrogen or C_{1-6}alkyl or together with the nitrogen to which they are attached, R^{36} and R^{37} form a 5- to 6-membered heterocyclic ring, which ring may be optionally substituted by an oxo group and, which, when the ring is 6-membered, may optionally contain one oxygen or sulfur atom or an NH group or a group NR^{43}, wherein R^{43} is C_{1-6}alkyl, COR^{44} or CO_2R^{45}, wherein R^{44} and R^{45} are independently hydrogen or C_{1-6}alkyl;

R^{38} is hydrogen or C_{1-6}alkyl;

R^{39} is C_{1-6}alkoxy, CO_2H, CO_2C_{1-6}alkyl or $CONR^{36}R^{37}$;

R^{40} is C_{1-6}alkyl;

R^{41} and R^{42} are independently hydrogen or C_{1-6}alkyl;

P is a 5 to 7-membered heterocyclic ring containing 1 to 4 heteroatoms selected from oxygen, nitrogen or sulfur;

a is 1, 2, 3 or 4;

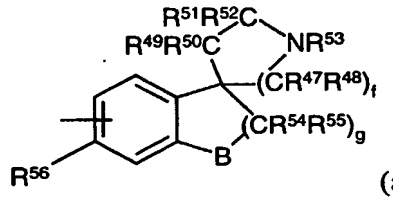
b is 0, 1, 2 or 3;

c is 1, 2 or 3;

d is 0, 1, 2, 3, 4, 5, or 6; and

e is 1, 2, 3, 4, 5 or 6;

and further wherein, when Ar is (i), (ii) or (iii), and A is $CONR^{46}$, NHCO, or CH_2NH, wherein R^{46} is hydrogen or C_{1-6}alkyl, E represents (a):



(a);

R^{47}, R^{48}, R^{49}, R^{50}, R^{51}, R^{52}, R^{54}, and R^{55} are independently hydrogen or C_{1-6}alkyl;

R^{53} is hydrogen, C_{1-6}alkyl, or C_{3-7}cycloalkyl;

R^{56} is hydrogen, C_{1-6}alkyl, trifluoromethyl, hydroxy or halogen, or R^{56} and R^{46} together form a group -D- where D is $(CR^{57}R^{58})_h$ or D is $(CR^{57}R^{58})_i$ -G and G is oxygen, sulfur, $CR^{57}=CR^{58}$, $CR^{57}=N$, or N=N;

B is oxygen, $CR^{59}R^{60}$, or NR^{61}, or B is a group $S(O)_j$;

R^{57}, R^{58}, R^{59}, R^{60}, and R^{61} are independently hydrogen or C_{1-6}alkyl;

f is 1, 2 or 3;

g is 1, 2 or 3;

h is 2, 3, or 4;

i is 0, 1, 2, or 3;

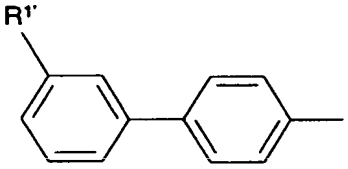
j is 0, 1 or 2;

Suitably, Ar is (i), (ii), or (iii). Preferably, Ar is (i) or (ii).

Suitably, when Ar is (i) or (ii), the terminal phenyl group in (i) and (ii) can be attached to the phenyl group bearing group A in any position. Preferably the terminal phenyl ring is attached to the phenyl bearing group A in a position meta or para to group A, more preferably para to group A.

Suitably, P is a 5- to 7-membered heterocyclic ring containing 1 to 4 heteroatoms selected from oxygen, nitrogen, or sulfur. Suitable heterocyclic rings include aromatic groups such as thienyl, furyl, pyrrolyl, triazolyl, diazolyl, imidazolyl, oxazolyl, thiazolyl, oxadiazolyl, isothiazolyl, isoxazolyl, thiadiazolyl, pyridyl, pyrimidyl, pyrazinyl, and dioxanyl. Saturated and partially saturated rings are also within the scope of the invention, in particular rings including an oxo or thioxo moiety such as lactams and thiolactams. Suitably, the heterocyclic ring can be linked to the remainder of the molecule via a carbon atom, or, when present, a nitrogen atom. Suitable substituents for these rings include one or more of $R^{4'}$.

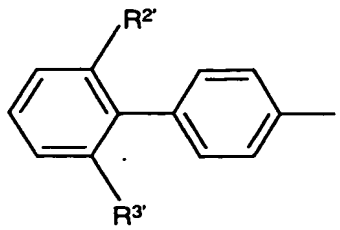
A particularly preferred group of compounds for use herein are those compounds of the formula (I), or a pharmaceutically acceptable salt thereof, wherein, preferably, Ar is represented by sub-formula $(i)_a$:



$(i)_a$

in which $R^{1'}$ are suitably hydrogen, CO_2R^{22}, wherein R^{22} is C_{1-6}alkyl, or halo. Preferably, $R^{1'}$ is hydrogen, CO_2R^{22}, wherein R^{22} is ethyl, or chloro.

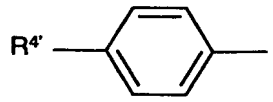
Alternatively, another preferred embodiment of this invention is wherein, preferably, Ar is represented by sub-formula $(i)_b$:



$(i)_b$

in which $R^{2'}$ and $R^{3'}$ are suitably halogen. Preferably, $R^{2'}$ and $R^{3'}$ are chloro.

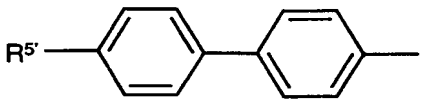
Alternatively, another preferred embodiment of this invention is wherein, preferably, Ar is represented by sub-formula $(iii)_a$:



$(iii)_a$

in which, $R^{4'}$ is suitably C_{3-6}cycloalkyl, preferably cyclohexyl, or suitably halo, preferably iodo.

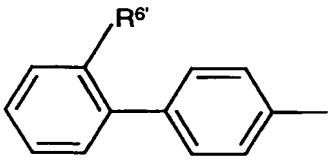
Alternatively, another preferred embodiment of this invention is when Ar is represented by sub-formula $(i)_c$:



$(i)_c$

wherein $R^{5'}$ is suitably hydroxy.

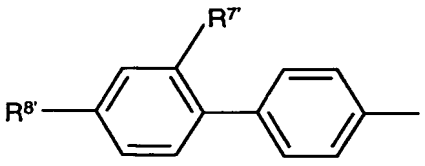
Alternatively, another preferred embodiment of this invention is when Ar is represented by sub-formula $(i)_d$:



$(i)_d$

wherein $R^{6'}$ is suitably halogen. Preferably, $R^{6'}$ is chloro.

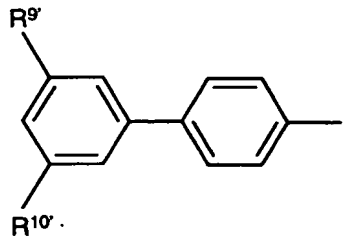
Alternatively, another preferred embodiment of this invention is when Ar is represented by sub-formula $(i)_e$:



$(i)_e$

wherein $R^{7'}$ and $R^{8'}$ are suitably, independently, halogen. Preferably, $R^{7'}$ and $R^{8'}$ are chloro.

Alternatively, another preferred embodiment of this invention is when Ar is represented by sub-formula $(i)_f$:



$(i)_f$

wherein $R^{9'}$ and $R^{10'}$ are suitably, independently, halogen. Preferably, $R^{9'}$ and $R^{10'}$ are chloro.

Suitably, when Ar is $(i)_a$, $(i)_b$, $(i)_c$, $(i)_d$, $(i)_e$, $(i)_f$, or $(iii)_a$, and E represents (b), the following embodiments are preferred. Suitably, A represents $CONR^{46}$, NHCO, or CH_2NH where R^{46} is hydrogen or C_{1-6}alkyl. Preferably group A represents $CONR^{46}$, where R^{46} is hydrogen or C_{1-6}alkyl. More preferably A is $CONR^{46}$ and R^{46} is hydrogen. The group A can be located at any open position on the phenyl ring. Preferably, the group A is located para to group B. Preferably B is oxygen, R^{47}, R^{48}, R^{49}, R^{50}, R^{51}, R^{52}, R^{54}, and R^{55} are preferably hydrogen, g is preferably 1, R^{53} is preferably C_{1-6}alkyl, more preferably C_{3-6}alkyl, most preferably isopropyl, f is preferably 2, and R^{56} is preferably hydrogen.

The term "C_{1-6}alkyl" is used herein at all occurrences to mean a straight or branched chain radical of 1 to 6 carbon atoms, unless the chain length is limited thereto, including, but not limited to methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, and the like.

The terms "halo" or "halogen" are used interchangeably herein at all occurrences to mean radicals derived from the elements chlorine, fluorine, iodine and bromine.

The terms "cycloalkyl" and "cyclic alkyl" are used herein at all occurrences to mean cyclic radicals, preferably comprising 3 to 7 carbon atoms which may be mono- or bicyclo- fused ring systems which may additionally include unsaturation, including, but not limited to, cyclopropyl, cyclopentyl, cyclohexyl, 1,2,3,4-tetrahydronaphthyl, and the like.

The term "alkenyl" is used herein at all occurrences to mean a straight or branched chain radical of 2 to 6 carbon atoms, unless the length is limited thereto,

wherein there is at least one double bond between two of the carbon atoms in the chain, including, but not limited to, ethenyl, 1-propenyl, 2-propenyl, 2-methyl-1-propenyl, 1-butenyl, 2-butenyl, and the like.

The term "cycloalkenyl" is used herein to mean cyclic radicals, preferably of 5 to 8 carbons, which have at least one double bond between two of the carbon atoms in the ring, including but not limited to cyclopentenyl, cyclohexenyl, and the like.

The term "alkynyl" is used herein at all occurrences to mean a straight or branched chain radical of 2 to 8 carbon atoms, unless the chain length is limited thereto, wherein there is at least one triple bond between two of the carbon atoms in the chain, including, but not limited to, acetylene, 1- propylene, 2-propylene, and the like.

The term "aryl" is used herein at all occurrences to mean 5-14-membered substituted or unsubstituted aromatic ring(s) or ring systems which may include bi- or tri-cyclic systems, including, but not limited to phenyl, naphthyl, and the like.

The term "aralkyl" is used herein at all occurrences to mean an aryl moiety as defined above, which is connected to an alkyl moiety as defined above, for example, benzyl or phenethyl, and the like.

The term "alkoxy" is used herein at all occurrences to mean a straight or branched chain radical of 1 to 6 carbon atoms, unless the chain length is limited thereto, bonded to an oxygen atom, including, but not limited to, methoxy, ethoxy, n- propoxy, isopropoxy, and the like.

The terms "hydroxyC_{1-6}alkyl" and "hydroxyalkyl" are used herein interchangeably to mean an hydroxyl group bonded to a C_{1-6}alkyl group as defined above, including, but not limited to methanol, ethanol, n-propanol, isopropanol, n-butanol, sec-butanol, isobutanol, tert-butanol, and the like.

The term "C_{1-4}alkoxyalkyl" is used herein at all occurrences to mean a C_{1-4}alkoxy group as defined above bonded to an alkyl group as defined above, such as an ether, e.g., $-CH_2-CH_2-O-CH_2-CH_2-CH_3$.

The term "hydroxyC_{1-6}alkoxy" is used herein at all occurrences to mean an hydroxyl group bonded to an alkoxy group as defined above, e.g., $-O-CH_2-CH(OH)CH_3$.

The term "C_{1-6}alkoxyC_{1-6}alkoxy" is used herein at all occurrences to mean an alkoxy group as defined above, substituted with an alkoxy group as defined above.

The term "acyloxy" is used herein at all occurrences to mean a moiety

–O-C(O)-R, wherein R is hydrogen or C_{1-6}alkyl.

The term " C_{1-4}alkanoyl " is used herein at all occurrences to mean a -C(O)C_{1-4}alkyl group wherein the alkyl portion is as defined above.

The term "heteroatom" is used herein at all occurrences to mean an oxygen atom, a sulfur atom or a nitrogen atom. It will be recognized that when the heteroatom is nitrogen, it may form an NR_aR_b moiety, wherein R_a and R_b are, independently, hydrogen or C_1 to C_6 alkyl, or together with the nitrogen to which they are bound, form a saturated or unsaturated 5-, 6- or 7-membered ring, including, but not limited to, pyrrolidine, piperidine, piperazine, morpholine, pyridine, and the like. It will be recognized that the saturated or unsaturated 5-, 6- or 7-membered ring may optionally have one or more additional heteroatoms in the ring.

The term "oxo" is used herein at all occurrences to mean a double bonded oxygen atom attached to a chemical moiety as a substituent.

The term "CCR5 mediated disease state" is used herein at all occurrences to mean any disease state which is mediated (or modulated) by the CCR5 receptor.

Suitably, pharmaceutically acceptable salts of formula (I) include, but are not limited to, salts with inorganic acids such as hydrochloride, sulfate, phosphate, diphosphate, hydrobromide, and nitrate, or salts with an organic acid such as malate, maleate, fumarate, tartrate, succinate, citrate, acetate, lactate, methanesulfonate, p-toluenesulfonate, palmitate, salicylate, and stearate.

Among the preferred compounds of the invention are the following compounds:

N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide;

3'-Ethoxycarbonyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Iodo-N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide;

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide;

4'-Hydroxy-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2',4'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

3',5'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-3-carboxamide trifluoroacetate);

3'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate); and

N-(1'-Ethyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide, or a pharmaceutically acceptable salt or solvate thereof.

Among the more preferred compounds of the invention are the following compounds:

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide; and

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate), or a pharmaceutically acceptable salt or solvate thereof.

Formulation of Pharmaceutical Compositions

The pharmaceutically effective compounds of this invention (and the pharmaceutically acceptable salts thereof) are administered in conventional dosage forms prepared by combining a compound of formula (I) ("active ingredient") in an amount sufficient to treat COPD, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, atherosclerosis, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, inflammatory bowel disease, and HIV infection, ("CCR5-mediated disease states") with standard pharmaceutical carriers or diluents according to conventional procedures well known in the art. These procedures may involve mixing, granulating and compressing or dissolving the ingredients as appropriate to the desired preparation.

The pharmaceutical carrier employed may be, for example, either a solid or liquid. Exemplary of solid carriers are lactose, terra alba, sucrose, talc, gelatin, agar, pectin, acacia, magnesium stearate, stearic acid and the like. Exemplary of liquid

carriers are syrup, peanut oil, olive oil, water and the like. Similarly, the carrier or diluent may include time delay material well known to the art, such as glyceryl monostearate or glyceryl distearate alone or with a wax.

A wide variety of pharmaceutical forms can be employed. Thus, if a solid carrier is used, the preparation can be tableted, placed in a hard gelatin capsule in powder or pellet form or in the form of a troche or lozenge. The amount of solid carrier will vary widely but preferably will be from about 25 mg to about 1000 mg. When a liquid carrier is used, the preparation will be in the form of a syrup, emulsion, soft gelatin capsule, sterile injectable liquid such as an ampule or nonaqueous liquid suspension.

The active ingredient may also be administered topically to a mammal in need of treatment or prophylaxis of CCR5 mediated disease states. The amount of active ingredient required for therapeutic effect on topical administration will, of course, vary with the compound chosen, the nature and severity of the disease state being treated and the mammal undergoing treatment, and is ultimately at the discretion of the physician. A suitable dose of an active ingredient is 1.5 mg to 500 mg for topical administration, the most preferred dosage being 1 mg to 100 mg, for example 5 to 25 mg administered two or three times daily.

By topical administration is meant non-systemic administration and includes the application of the active ingredient externally to the epidermis, to the buccal cavity and instillation of such a compound into the ear, eye and nose, and where the compound does not significantly enter the blood stream. By systemic administration is meant oral, intravenous, intraperitoneal and intramuscular administration.

While it is possible for an active ingredient to be administered alone as the raw chemical, it is preferable to present it as a pharmaceutical formulation. The active ingredient may comprise, for topical administration, from 0.001% to 10% w/w, e.g. from 1% to 2% by weight of the formulation although it may comprise as much as 10% w/w but preferably not in excess of 5% w/w and more preferably from 0.1% to 1% w/w of the formulation.

The topical formulations of the present invention, both for veterinary and for human medical use, comprise an active ingredient together with one or more acceptable carrier(s) therefor and optionally any other therapeutic ingredient(s). The carrier(s) must be 'acceptable' in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof.

Formulations suitable for topical administration include liquid or semi-liquid preparations suitable for penetration through the skin to the site of inflammation such

as liniments, lotions, creams, ointments or pastes, and drops suitable for administration to the eye, ear or nose.

Drops according to the present invention may comprise sterile aqueous or oily solutions or suspensions and may be prepared by dissolving the active ingredient in a suitable aqueous or alcoholic solution of a bactericidal and/or fungicidal agent and/or any other suitable preservative, and preferably including a surface active agent. The resulting solution may then be clarified by filtration, transferred to a suitable container which is then sealed and sterilized by autoclaving or maintaining at 98-100°C for half an hour. Alternatively, the solution may be sterilized by filtration and transferred to the container by an aseptic technique. Examples of bactericidal and fungicidal agents suitable for inclusion in the drops are phenylmercuric nitrate or acetate (0.002%), benzalkonium chloride (0.01%) and chlorhexidine acetate (0.01%). Suitable solvents for the preparation of an oily solution include glycerol, diluted alcohol and propylene glycol.

Lotions according to the present invention include those suitable for application to the skin or eye. An eye lotion may comprise a sterile aqueous solution optionally containing a bactericide and may be prepared by methods similar to those for the preparation of drops. Lotions or liniments for application to the skin may also include an agent to hasten drying and to cool the skin, such as an alcohol or acetone, and/or a moisturizer such as glycerol or an oil such as castor oil or arachis oil.

Creams, ointments or pastes according to the present invention are semi-solid formulations of the active ingredient for external application. They may be made by mixing the active ingredient in finely-divided or powdered form, alone or in solution or suspension in an aqueous or non-aqueous fluid, with the aid of suitable machinery, with a greasy or non-greasy basis. The basis may comprise hydrocarbons such as hard, soft or liquid paraffin, glycerol, beeswax, a metallic soap; a mucilage; an oil of natural origin such as almond, corn, arachis, castor or olive oil; wool fat or its derivatives, or a fatty acid such as stearic or oleic acid together with an alcohol such as propylene glycol. The formulation may incorporate any suitable surface active agent such as an anionic, cationic or non-ionic surfactant such as esters or polyoxyethylene derivatives thereof. Suspending agents such as natural gums, cellulose derivatives or inorganic materials such as silicaceous silicas, and other ingredients such as lanolin, may also be included.

The active ingredient may also be administered by inhalation. By "inhalation" is meant intranasal and oral inhalation administration. Appropriate dosage forms for such administration, such as an aerosol formulation or a metered dose inhaler, may be

prepared by conventional techniques. The daily dosage amount of the active ingredient administered by inhalation is from about 0.1 mg to about 100 mg per day, preferably about 1 mg to about 10 mg per day.

In one aspect, this invention relates to a method of treating COPD, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, atherosclerosis, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, inflammatory bowel disease, and HIV infection, all in mammals, preferably humans, which comprises administering to such mammal an effective amount of a CCR5 receptor modulator, in particular, a compound as depicted in formula (I).

By the term "treating" is meant either prophylactic or therapeutic therapy. Such formula (I) compound can be administered to such mammal in a conventional dosage form prepared by combining the formula (I) compound with a conventional pharmaceutically acceptable carrier or diluent according to known techniques. It will be recognized by one of skill in the art that the form and character of the pharmaceutically acceptable carrier or diluent is dictated by the amount of active ingredient with which it is to be combined, the route of administration and other well-known variables. The formula (I) compound is administered to a mammal in need of treatment for COPD, asthma and atopic disorders (for example, atopic dermatitis and allergies), rheumatoid arthritis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, atherosclerosis, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, inflammatory bowel disease, and HIV infection, in an amount sufficient to decrease symptoms associated with these disease states. The route of administration may be oral or parenteral.

The term parenteral as used herein includes intravenous, intramuscular, subcutaneous, intra-rectal, intravaginal or intraperitoneal administration. The subcutaneous and intramuscular forms of parenteral administration are generally preferred. The daily parenteral dosage regimen will preferably be from about 30 mg to about 300 mg per day of active ingredient. The daily oral dosage regimen will preferably be from about 100 mg to about 2000 mg per day of active ingredient.

It will be recognized by one of skill in the art that the optimal quantity and spacing of individual dosages of a formula (I) compound will be determined by the nature and extent of the condition being treated, the form, route and site of administration, and the particular mammal being treated, and that such optimums

can be determined by conventional techniques. It will also be appreciated by one of skill in the art that the optimal course of treatment, i.e., the number of doses of the formula (I) compound given per day for a defined number of days, can be ascertained by those skilled in the art using conventional course of treatment determination tests.

Methods of Preparation

The compounds of formula (I) can be prepared by art-recognized procedures from known or commercially available starting materials. If the starting materials are unavailable from a commercial source, their synthesis is described herein, or they can be prepared by procedures known in the art.

Compounds of formula (I) wherein Ar is represented by group (i), A is CONH and E is represented by group (a), were prepared according the methods of international application publication number WO 96/11934, published 25 April 1996.

Compounds of formula (I) wherein Ar is represented by group (i) and A is represented by $CONR^{46}$ and E is represented by group (a), where R^{56} and R^{46} are represented by the group D, where D is $(CR^{57}R^{58})_h$, where h is 2, 3, or 4 and R^{57} and R^{58} are independently hydrogen or C_{1-6}alkyl or D is $(CR^{57}R^{58})_i$ -G where i is 0, 1, 2, or 3 and G is oxygen, sulfur or $CR^{57}=CR^{58}$, were prepared according the methods of international application publication number WO 96/19477, published 27 June 1996.

Compounds of formula (I) wherein Ar is (i) or (ii), and A is $CONR^{46}$ or NHCO, and E is represented by group (a), were prepared according to the methods of international application publication number WO 96/11934, published 25 April 1996, and WO 96/19477, published 27 June 1996. Other applications covering the spiro compounds are WO 97/17350 published 15 May 1997; WO 97/34900 published 25 September 1997; WO 97/34901 published 25 September 1997; WO 97/35861 published 2 October 1997; and WO 97/35862 published 2 October 1997.

The invention will now be described by reference to the following examples which are merely illustrative and are not to be construed as a limitation of the scope of the present invention. In the Examples, mass spectra were performed upon a VG Zab mass spectrometer using fast atom bombardment, unless otherwise indicated.

EXAMPLES

Preparation 1

Preparation of 2',6'-Dichloro-4-biphenylcarboxylic acid

A mixture of 2,6-dichloro-1-iodobenzene (0.5 g, 1.8 mmol), 4-carboxybenzeneboronic acid (0.3 g, 1.8 mmol), tetrakis(triphenylphosphine)-palladium(0) (40 mg), and sodium carbonate (0.68 g, 6.4 mmol) in a 1:1 mixture of 1,2-dimethoxyethane and water (26 mL) was heated at reflux for 16 h. The mixture was cooled and extracted with ether. The aqueous phase was acidified with 3M hydrochloric acid, allowed to stand for 16 h, and filtered. The filter cake was washed with water and dried to give the title compound.

Preparation 2

Preparation of N-[1'-(1-Methylethyl)spiro[benzofuran-3(2H),4'-piperidin]-5-amine

a) 5- and 7-nitro-spiro[benzofuran-3(2H),4'-piperidine]

A solution of 1'-methyl-5- and 7-nitro-spiro[benzofuran-3(2H),4'-piperidine] (WO 96/11934) (3 g, 12 mmol) and diisopropylethylamine (2.5 g, 19 mmol) in 1,2-dichloroethane (80 mL) was treated with 1-chloroethyl chloroformate (2.3 g, 16 mmol) at RT, stirred for 1 h, and heated to reflux for 20 min. The mixture was cooled, concentrated *in vacuo*, and the residue was dissolved in methanol and heated to reflux for 2 h, concentrated *in vacuo*, and the residue was partitioned between dichloromethane (250 mL) and 5% sodium bicarbonate (50 mL). The organic phase was washed with 5% sodium bicarbonate (50 mL) and the combined aqueous phase was extracted with dichloromethane (2 X 50 mL). The combined organic phase was dried (Na_2SO_4) and concentrated to afford the title compound (2. 65 g).

b) 1'-(tert-butoxycarbonyl)-5-nitro-spiro[benzofuran-3(2H),4'-piperidine]

A solution of the compound of Preparation 2(a)(2.65 g, 1.13 mmol) in tetrahydrofuran (300 mL) was treated with di-tert-butyl dicarbonate (2.6 g, 12 mmol) and stirred at RT for 16 h. The mixture was concentrated *in vacuo* and the residue was crystallized from methanol to afford the title compound (2.1 g).

c) 5-nitro-spiro[benzofuran-3(2H),4'-piperidine]

A solution of the compound of Preparation 2(b)(2.1 g, 6.3 mmol) in dichloromethane (50 mL) and trifluoroacetic acid (10 mL) was kept at RT for 5 h, concentrated *in vacuo*, and the residue was partitioned between dichloromethane (300 mL) and 5% sodium bicarbonate. The organic phase was washed with 5% sodium bicarbonate and the combined aqueous washes were extracted with dichloromethane. The combined organic phase was dried (Na_2SO_4) and concentrated *in vacuo* to give the title compound (1.45 g): MS(ES) m/e 235.1 $[+H]^+$.

d) 5-nitro-1'-(1-methylethyl)spiro[benzofuran-3(2H),4'-piperidine]

A mixture of the compound of Preparation 2(c) (1.45 g, 6.2 mmol), powdered potassium carbonate (0.86 g, 6.2 mmol) and dimethylformamide (50 mL) containing 2-iodopropane (1.1 g, 6.4 mmol) was stirred and heated to 50°C for 4 h, treated with 2-iodopropane (0.17 g, 1 mmol) at 50°C for 90 min, and treated with 2-iodopropane (0.1 g, 1 mmol) at 50°C for 2 h. The mixture was concentrated *in vacuo* and the residue was partitioned between ethyl acetate (200 mL) and water (20 mL). The organic phase was washed, dried ($MgSO_4$), concentrated *in vacuo*, and the residue was chromatographed (silica gel, 5% methanol/dichloromethane) to give the title compound (0.85 g).

e) N-[1'-(1-methylethyl)spiro[benzofuran-3(2H),4'-piperidin]-5-amine

A solution of the compound of Preparation 2(d) (0.78 g, 2.8 mmol) in methanol (250 mL) containing 10% palladium-on-carbon (0.375 g) was shaken in a hydrogen atmosphere (40 psi) for 40 min, filtered, and concentrated *in vacuo* to afford the title compound (0.6 g).

Preparation 3

Preparation of 3'-Chloro-4-biphenylcarboxylic acid

a) ethyl 3'-chloro-4-biphenylcarboxylic acid

A solution of ethyl 4-iodobenzoate (2 g, 7.2 mmol) and tetrakis(triphenylphosphine)palladium(0) (0,46 g, 0.4 mmol) in tetrahydrofuran (75 mL) was stirred and treated dropwise with a solution of 0.5M 3-chlorophenylzinc iodide in tetrahydrofuran (15 mL, 7.5 mmol). The resulting mixture was stirred for 16 h, concentrated *in vacuo*, and the residue was taken up in ethyl acetate, washed with water, dried ($MgSO_4$), and concentrated *in vacuo*. The residue was slurried with 10% ethyl acetate/hexane and the mixture was briefly heated to reflux and the supernatant was decanted. The supernatant was cooled, allowed to stand for 30 min, and filtered to remove solids. The filtrate was chromatographed (silica gel, 10% ethyl acetate/hexane to give the title compound.

a) 3'-chloro-4-biphenylcarboxylic acid

A mixture of the compound of Preparation 3(a) and 1.25M sodium hydroxide (10 mL) was heated to 50°C for 16 h, cooled, reduced in volume *in vacuo* to 10 mL, diluted with water (50 mL), and acidified with 2M hydrochloric acid to give a colorless solid which was filtered and air dried to give the title compound.

Example 1

Preparation of N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide

a) N-(1'-methylspiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide

A solution of 4-biphenylcarbonyl chloride (0.32 g, 1.5 mmol), prepared from 4-biphenylcarboxylic acid and thionyl chloride, was added to a solution of 1'-methyl-spiro[benzofuran-3(2H),4'-piperidin]-5-amine [J. Med. Chem. (1998) 41, 1218-1235] and diisopropylethylamine in dichloromethane. The resulting mixture was stirred for 16 h, extracted with 5% aqueous sodium carbonate, dried (Na_2SO_4), and concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, methanol/dichloromethane) to give the title compound: MS(ES) m/e 399.2 $[M+H]^+$.

b) N-(spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide

Following the procedure of Preparation 2(a), except substituting the compound of Example 1(a) for 1'-methyl-5- and 7-nitro-spiro[benzofuran-3(2H),4'-piperidine] (WO 96/11934), afforded the title compound.

c) N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide

Following the procedure of Preparation 2(d), except substituting the compound of Example 1(b) for the compound of Preparation 2(c), afforded the title compound: MS (ES) m/e 427.1 $[M+H]^+$.

Example 2

Preparation of 4-Iodo-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide

The compound of Preparation 2 (25 mg, 0.1 mmol), 4-iodobenzoic acid (25 mg, 0.1 mmol) and benzotriazol-1-yloxytris(dimethylamino)phosphonium hexafluorophosphate (49 mg, 0.11 mmol) were dissolved in acetonitrile (5 mL), treated with diisopropylethylamine (26 mg, 0.2 mmol), stirred overnight at RT, and concentrated *in vacuo*. The residue was dissolved in dimethylsulfoxide (1.5 mL) and chromatographed by HPLC (ODS-A, 20 X 50 mm, 20 mL/min, A:acetonitrile B:water-0.1% trifluoroacetic acid, 20-80% during 10 min, UV detection at 254 nm). Fractions containing the title compound were combined, concentrated *in vacuo*, basified with 2.5 N sodium hydroxide and extracted with dichloromethane. The

organic phase was dried (Na_2SO_4) and concentrated *in vacuo* to afford the title compound: MS(ES) m/e 477.3 $[M+H]^+$.

Example 3

Preparation of 3'-Ethoxycarbonyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate

A solution of the compound of Example 2 (0.19 g, 0.4 mmol) and tetrakis(triphenylphosphine)palladium(0) (40 mg, 0.034 mmol) in tetrahydrofuran (5 mL) was treated with 3-(ethoxycarbonyl)phenylzinc iodide in tetrahydrofuran (0.5 M, 2 mL, 1 mmol), stirred for 2 h at RT, quenched with saturated ammonium chloride, and extracted with ether. The combined ether extract was washed with water, dried ($MgSO_4$) and concentrated *in vacuo*. The resulting residue was chromatographed by HPLC (ODS-A, 20 X 50 mm, A:acetonitrile B:water-0.1% trifluoroacetic acid, 10-90% during 10 min, UV detection at 254 nm) and fractions containing the title compound were combined, concentrated *in vacuo*, and chromatographed (silica gel, 5% methanol/dichloromethane) to afford the title compound (52 mg): MS(ES) m/e 499.1 $[M+H]^+$.

Example 4

Preparation of 2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate)

Following the procedure of Example 2, except substituting the compound of Preparation 1 for 4-iodobenzoic acid and substituting triethylamine for diisopropylethylamine afforded the title compound: MS(ES) m/e 495.1 $[M+H]^+$.

Example 5

Preparation of 4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide

Following the procedure of Example 2, except substituting 4-cyclohexylbenzoic acid for 4-iodobenzoic acid afforded the title compound: MS(ES) m/e 433.8 $[M+H]^+$.

Examples 6-11

Following the procedure of Example 2, except substituting 4'-hydroxy-4-biphenylcarboxylic acid, 2'-chloro-4-biphenylcarboxylic acid (WO 0040239), 2',4'-dichloro-4-biphenylcarboxylic acid (WO 0040239), 3',5'-dichloro-4-

biphenylcarboxylic acid (WO 0040239), 3-biphenylcarboxylic acid and the compound of Preparation 3(b) for 4-iodobenzoic acid gave the following compounds:

4'-hydroxy-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate): MS(ES) m/e 443.6 $[M+H]^+$;

2'-chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate): MS(ES) m/e 462.0 $[M+H]^+$;

2',4'-dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate): MS(ES) m/e 496.4 $[M+H]^+$;

3',5'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate): MS(ES) m/e 496.5 $[M+H]^+$;

N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-3-carboxamide trifluoroacetate): MS(ES) m/e 427.5 $[M+H]^+$; and

3'-chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate): MS(ES) m/e 462.1 $[M+H]^+$.

Example 12

Preparation of N-(1'-Ethyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide

Following the procedure of Procedure 2(d), except substituting the compound of Example 1(b) for the compound of Preparation 2(c) and substituting iodoethane for 2-iodopropane, afforded the title compound: MS (ES) m/e 412.9 $[M+H]^+$.

Biological Data:

CCR5 Receptor Binding Assay

CHO cell membranes (0.25×10^6 cell equivalents) derived from CHO cells stably transfected with CCR5 were incubated with 0.3 ^{125}I-RANTES in a 96 well plate for 45 min. at room temperature (final reaction volume 200 ul). The reaction was terminated by filtration and the filters (GF/C) were washed twelve times with a solution of phosphate buffered saline containing 0.1 % bovine serum albumin and 0.05 % NaN_3. The radioactivity bound to filters was measured by liquid scintillation spectrometry. Non-specific binding was determined in the presence of unlabelled RANTES (10 or 30 nM) and averages 30-50% of total binding.

CCR5 Receptor Functional Assay

The cellular functional assay used to assess antagonist activity of compounds was RANTES-induced Ca^{2+} mobilization in RBL 2H3 cells stably expressing the hCCR5 or mCCR5 receptor (RBL 2H3 hCCR5). Agonist activity is determined by Ca^{2+} mobilization in the same cells which is inhibitable by a selective CCR5 antagonist. Cells were grown to 80-100% confluency in T-150 flasks and washed with phosphate-buffered saline. Cells were lifted from the flasks by treating with 3 mL of 1 mM EDTA for 3 min. at room temperature and diluting to 2 X 10^6 cells/mL with Krebs Ringer Henseleit buffer (KRH; 118 mM NaCl, 4.6 mM KCl, 25 mM $NaHCO_3$, 1 mM KH_2PO_4 and 11 mM glucose) containing 5 mM HEPES (pH 7.4), 1 mM $CaCl_2$, 1 mM $MgCl_2$ and 0.1% BSA and centrifuged at 200g for 3 min. Cells were resuspended at 2 X 10^6 cells/mL in the same buffer with 2 μM Fura-2AM, and incubated for 35 min. at 37° C. Cells were centrifuged at 200 x g for 3 min. and resuspended in the same buffer without Fura-2AM, then incubated for 15 min. at 37° C to complete the hydrolysis of intracellular Fura-2AM, and then centrifuged as before. Cells (10^6 cells/mL) were resuspended in cold KRH with 5 mM HEPES (pH 7.4), 1 mM $CaCl_2$, 1 mM $MgCl_2$ and 0.1% gelatin and maintained on ice until assayed. For antagonist studies, aliquots (2 mL) of cells were prewarmed at 37° C for 5 min. in 3 mL plastic cuvettes and fluorescence measured in a fluorometer (Johnson Foundation Biomedical Group, Philadelphia, PA, USA) with magnetic stirring and temperature maintained at 37° C. Excitation was set at 340 nm and emission set at 510 nm. Various concentrations of antagonists or vehicle were added and fluorescence monitored for ~15 sec to ensure that there was no change in baseline fluorescence, followed by the addition of 33 nM RANTES. Maximal Ca^{2+} attained after 33 nM RANTES stimulation was calculated as described by Grynkiewicz *et al.*, (1985). The percent of maximal RANTES-induced Ca^{2+} was determined for each concentration of antagonist and the IC_{50}, defined as the concentration of test compound that inhibits 50% of the maximal 33 nM RANTES response, obtained from the concentration-response curves (5-7 concentrations of antagonists). Alternatively, this CCR5 receptor functional assay was performed on murine CCR5 (mCCR5) with a RANTES concentration of 2nM.

The compounds of this invention show CCR5 receptor modulator activity having IC_{50} values in the range of 0.0001 to 100 μM. The full structure/activity relationship has not yet been established for the compounds of this invention. However, given the disclosure herein, one of ordinary skill in the art can utilize the present assays in order to determine which compounds of formula (I) are modulators

of the CCR5 receptor and which bind thereto with an IC_{50} value in the range of 0.0001 to 100 μM.

All publications, including, but not limited to, patents and patent applications cited in this specification, are herein incorporated by reference as if each individual publication were specifically and individually indicated to be incorporated by reference herein as though fully set forth.

The above description fully discloses the invention including preferred embodiments thereof. Modifications and improvements of the embodiments specifically disclosed herein are within the scope of the following claims. Without further elaboration it is believed that one skilled in the art can, given the preceding description, utilize the present invention to its fullest extent. Therefore any examples are to be construed as merely illustrative and not a limitation on the scope of the present invention in any way. The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

What is claimed is:

1. A method of treating a CCR5-mediated disease state in mammals which comprises administering to a mammal in need of such treatment, an effective amount of a compound selected from:

N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide;

3'-Ethoxycarbonyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Iodo-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide; and

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide;

4'-Hydroxy-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2',4'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

3',5'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-3-carboxamide trifluoroacetate);

3'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate); and

N-(1'-Ethyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide, or a pharmaceutically acceptable salt or solvate thereof.

2. The method as claimed in claim 1, wherein the disease is selected from COPD, asthma and atopic disorders, rheumatoid arthritis, sarcoidosis, or idiopathic pulmonary fibrosis and other fibrotic diseases, atherosclerosis, psoriasis, autoimmune diseases such as multiple sclerosis, treating and/or preventing rejection of transplanted organs, inflammatory bowel disease, and HIV infection.

3. A compound selected from the group consisting of:

N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide;

3'-Ethoxycarbonyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Iodo-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide; and

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide;

4'-Hydroxy-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2',4'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

3',5'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-3-carboxamide trifluoroacetate);

3'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate); and

N-(1'-Ethyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide, or a pharmaceutically acceptable salt or solvate thereof.

4. A compound selected from the group consisting of:

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide; and

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate), or a pharmaceutically acceptable salt or solvate thereof.

5. A method of modulating the CCR5 receptor in mammals which comprises administering to a mammal in need of such inhibition, an effective amount of a compound selected from:

N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide;

3'-Ethoxycarbonyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

2',6'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate;

4-Iodo-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide; and

4-Cyclohexyl-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-benzenecarboxamide;

4'-Hydroxy-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

2',4'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

3',5'-Dichloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate);

N-(1'-Isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-3-carboxamide trifluoroacetate);

3'-Chloro-N-(1'-isopropyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide trifluoroacetate); and

N-(1'-Ethyl-spiro[benzofuran-3(2H),4'-piperidin]-5-yl)-1,1'-biphenyl-4-carboxamide, or a pharmaceutically acceptable salt or solvate thereof.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/06837

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61K 31/44; C07D 401/00
US CL :514/278; 546/18
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/278; 546/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CHEMICAL ABSTRACTS, MED LINE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 6,100,272 A (GASTER et al) 08 August 2000, see entire document.	1-5
A, P	US 6,107,328 A (PARSONS) 22 August 2000, see entire document.	1-5
A, P	US 6,166,034 A (KING) 26 December 2000, see entire document.	1-5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 16 MAY 2001	Date of mailing of the international search report 07 JUN 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer JAMES H. REAMER Telephone No. (703) 308-1235

Form PCT/ISA/210 (second sheet) (July 1998)*